NASA Goddard Space Flight Center

Information, Science & Technology Colloquium

6 May 2015

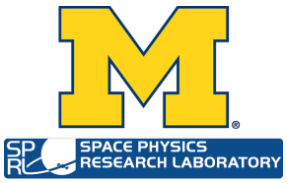
NASA Cyclone Global Navigation Satellite System (CYGNSS) Earth Venture Mission

Chris Ruf

Professor of Atmospheric Science and Electrical Engineering

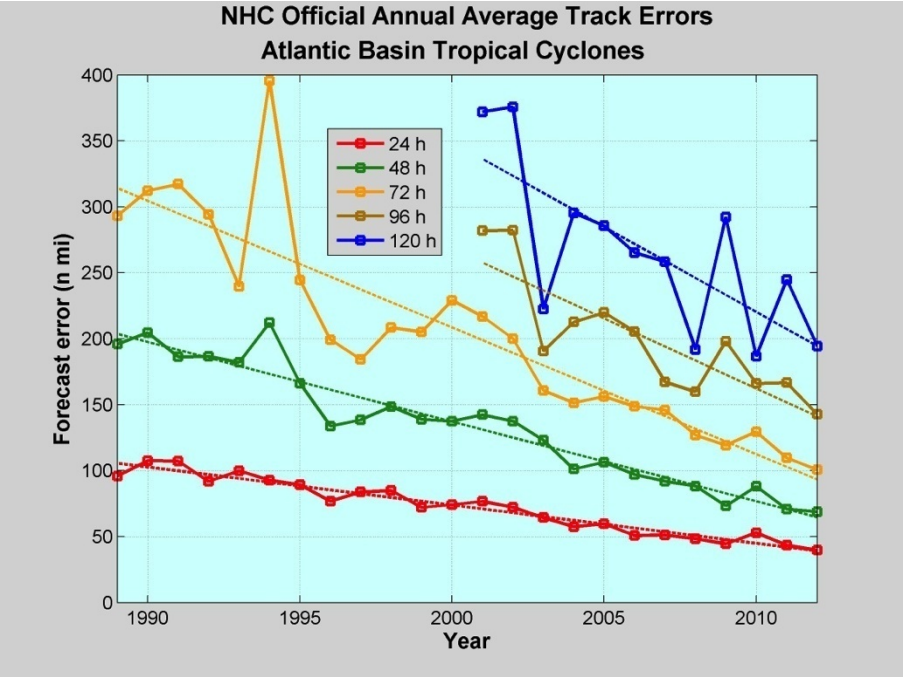
NASA CYGNSS Principal Investigator

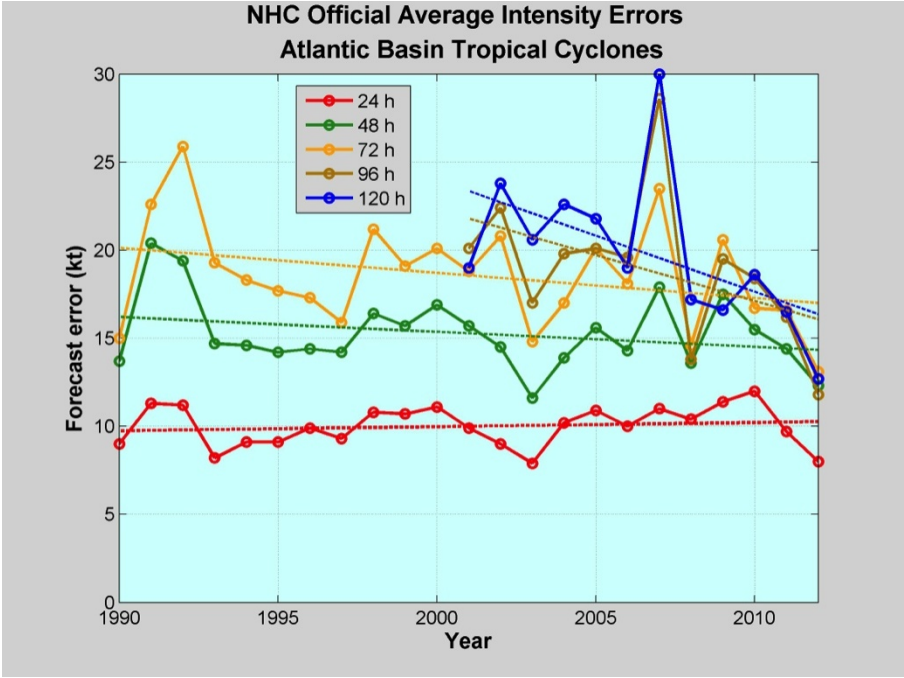
Space Physics Research Labortatory, University of Michigan



CYGNSS Science Motivation

- Tropical cyclone track forecasts have improved in accuracy by ~50% since 1990, largely as a result of improved mesoscale and synoptic modeling and data assimilation. In that same period, there has been essentially no improvement in the accuracy of intensity forecasts.

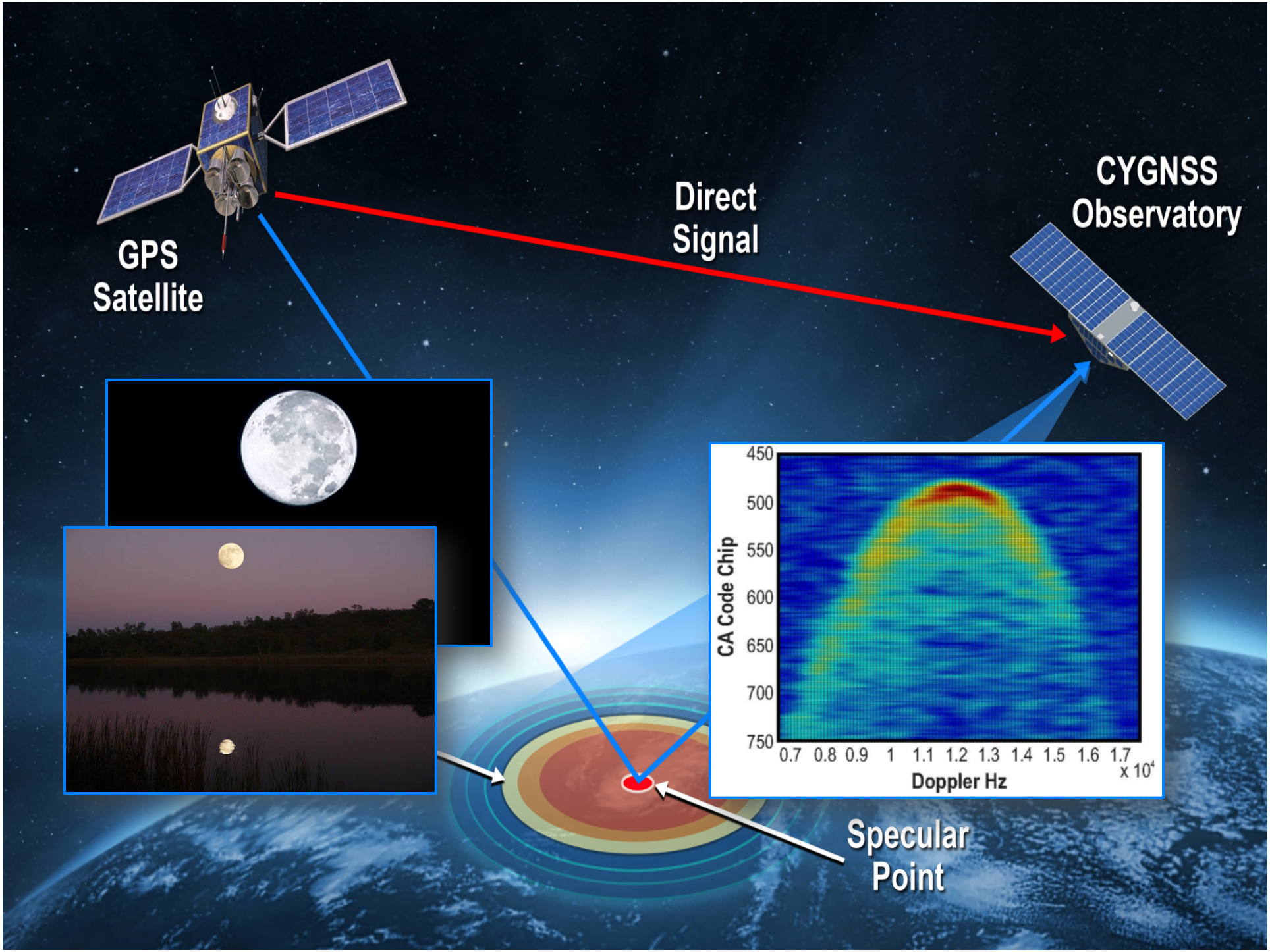




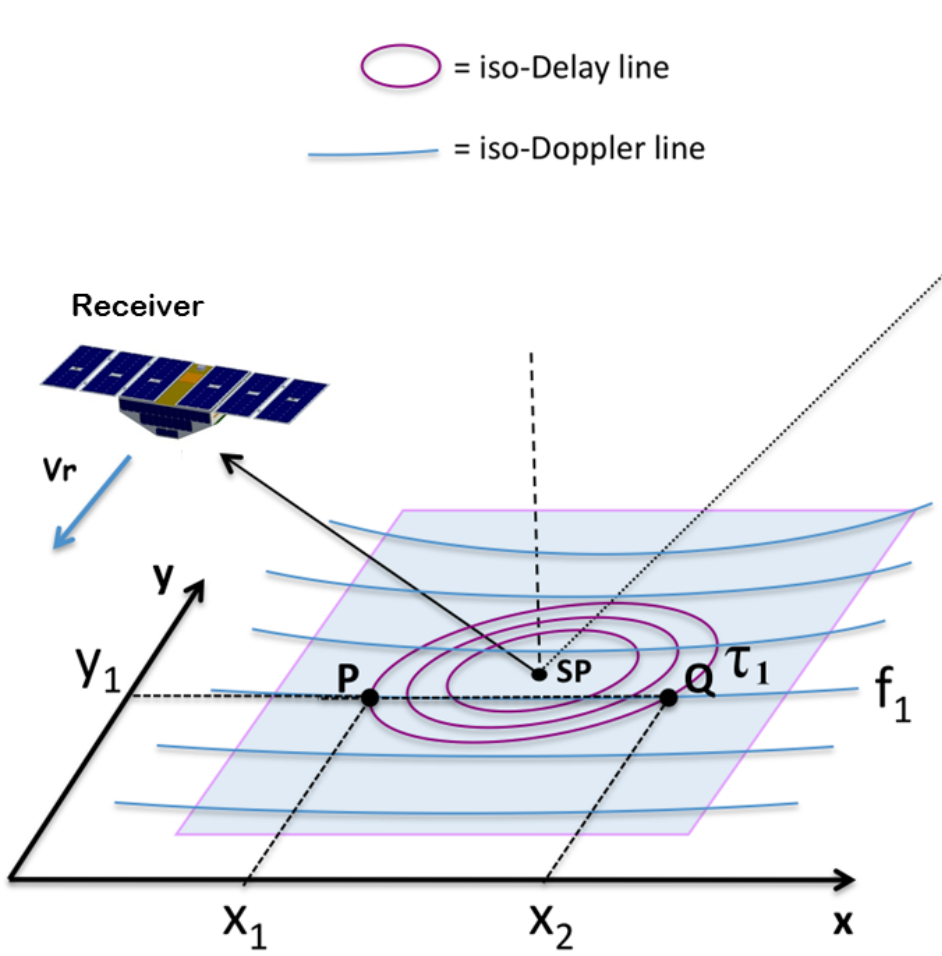
National Hurricane Center, http://www.nhc.noaa.gov/verification/verify5.shtml

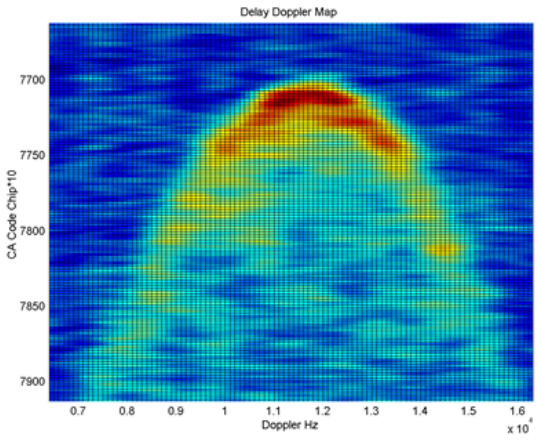
CYGNSS Objectives and Mission Design

- CYGNSS Objectives
  - Measure ocean surface wind speed in all precipitating conditions, including those experienced in the tropical cyclone (TC) eyewall
  - Measure ocean surface wind speed in the TC inner core with sufficient frequency to resolve genesis and rapid intensification
- CYGNSS Mission Design
  - Eight satellites in low earth orbit at 35^{o} inclination, each carrying a four-channel modified GPS receiver capable of bi-static radar measurements of GPS signals reflected by the ocean surface


GPS
Satellite
Direct
Signal
CYGNSS
Observatory
CA Code Chip
450
500
550
600
650
700
750
0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7
x 10^4
Doppler Hz
Specular
Point

Geometry of a GNSS-R Measurement of the Delay Doppler Map (DDM)

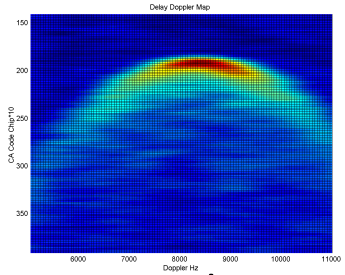




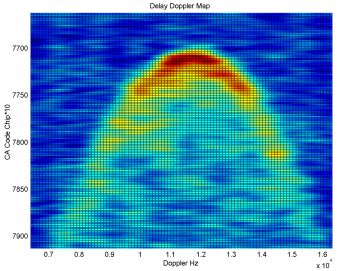
Spaceborne Empirical Demonstration of Ocean Wind Speed Retrievals by GNSS-R

DDMs measured by GNSS-R instrument (early version of CYGNSS science payload) deployed on UK-DMC-1 mission (launch 2003) with co-located NDBC buoys for wind speed ground truth

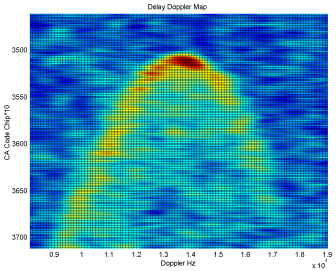
Software-based generation of DDMs in ground processing with <<1% duty cycle



2 m/s



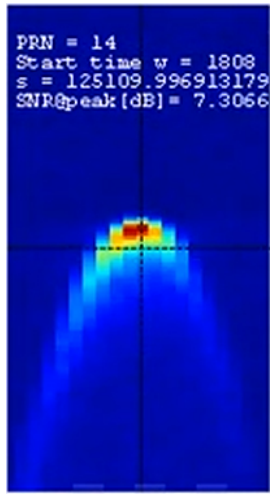
7 m/s

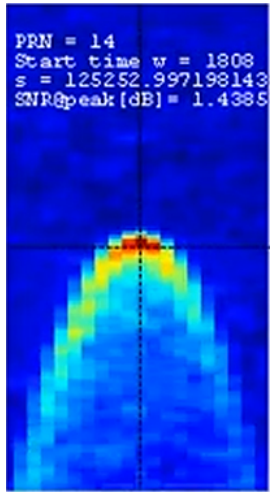


10 m/s

DDMs measured by GNSS-R instrument (nearly identical to CYGNSS DDMI science payload) deployed on TDS-1 mission (launch 2014). Ground truth co-location and intercomparison analysis in progress

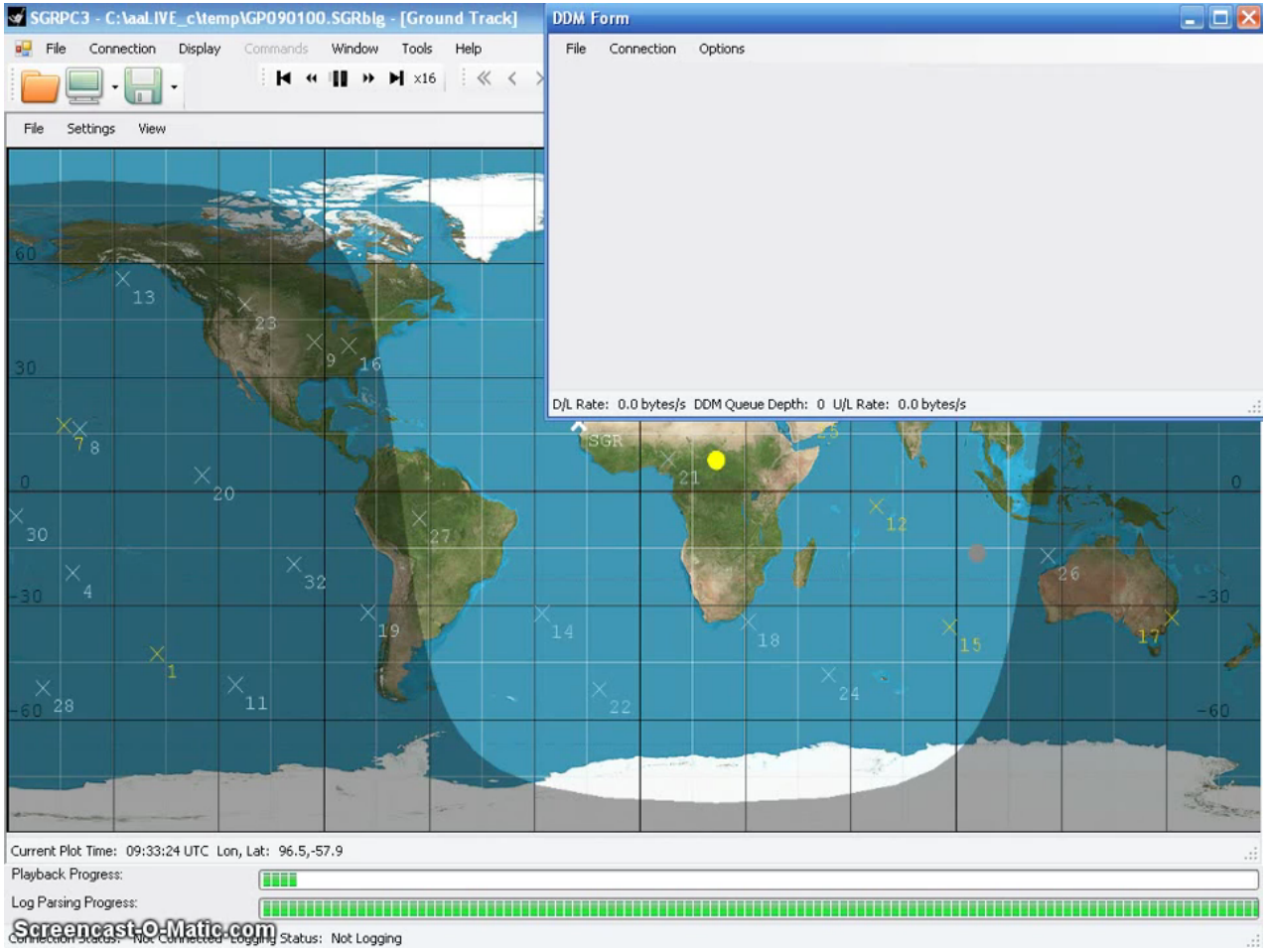
Firmware-based generation of DDMs in real time with 100% duty cycle





TechDemoSat; Orbital Test Flight

Launch 8 July 2014; GNSS-R Demo Sep 2014

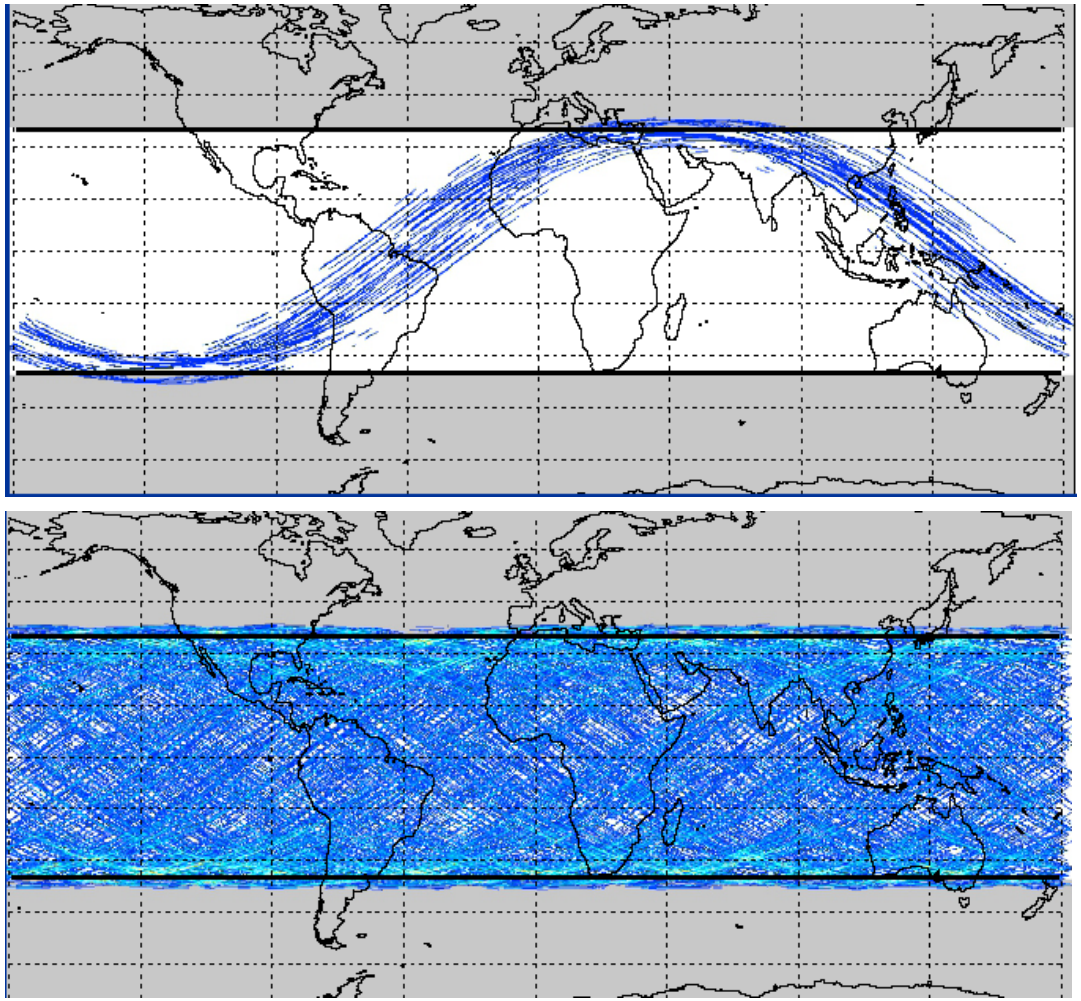


Observatory Separation from Deployment Module

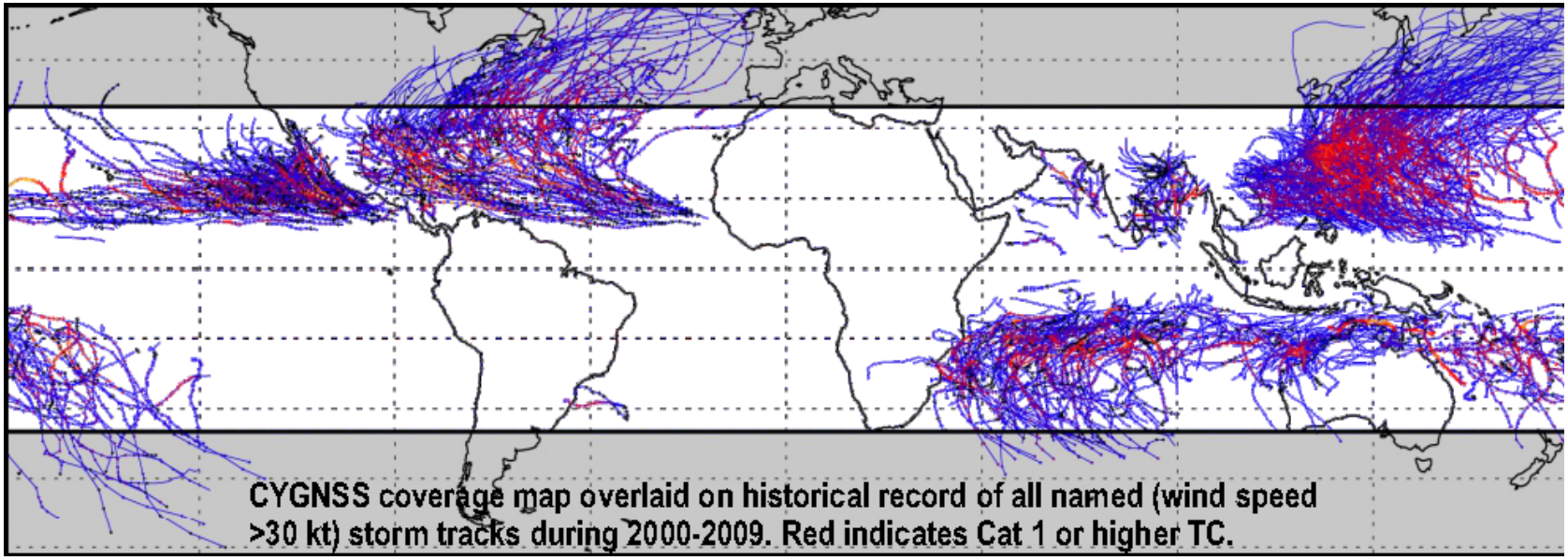
CYGNSS Specular Point Contacts and Spatial Sampling

CYGNSS Earth Coverage

- 90 min (one orbit) coverage showing all specular reflection contacts by each of 8 s/c
- 24 hr coverage provides nearly gap free spatial sampling within +/- 35 deg orbit inclination

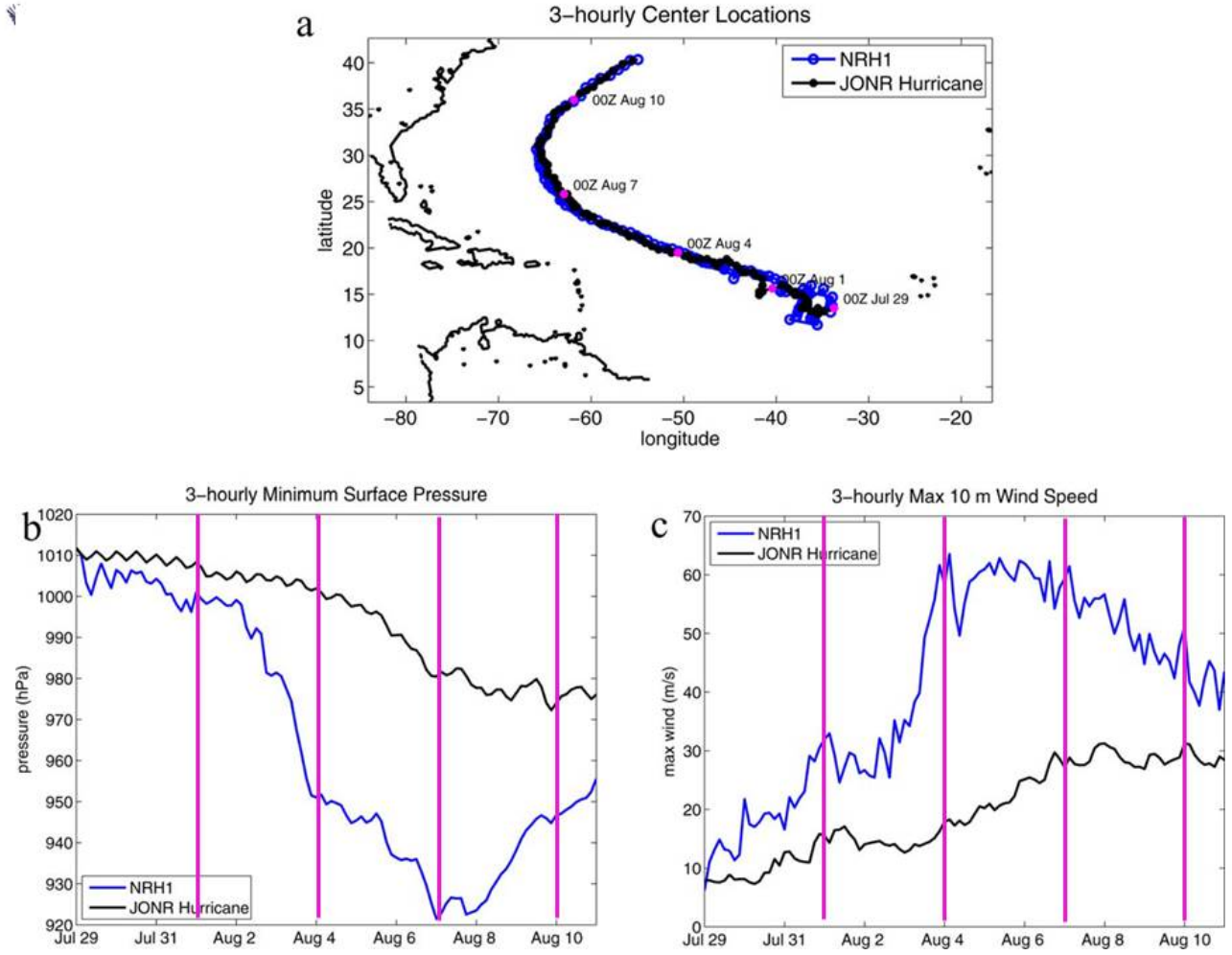


CYGNSS Historical Storm Track Overlay

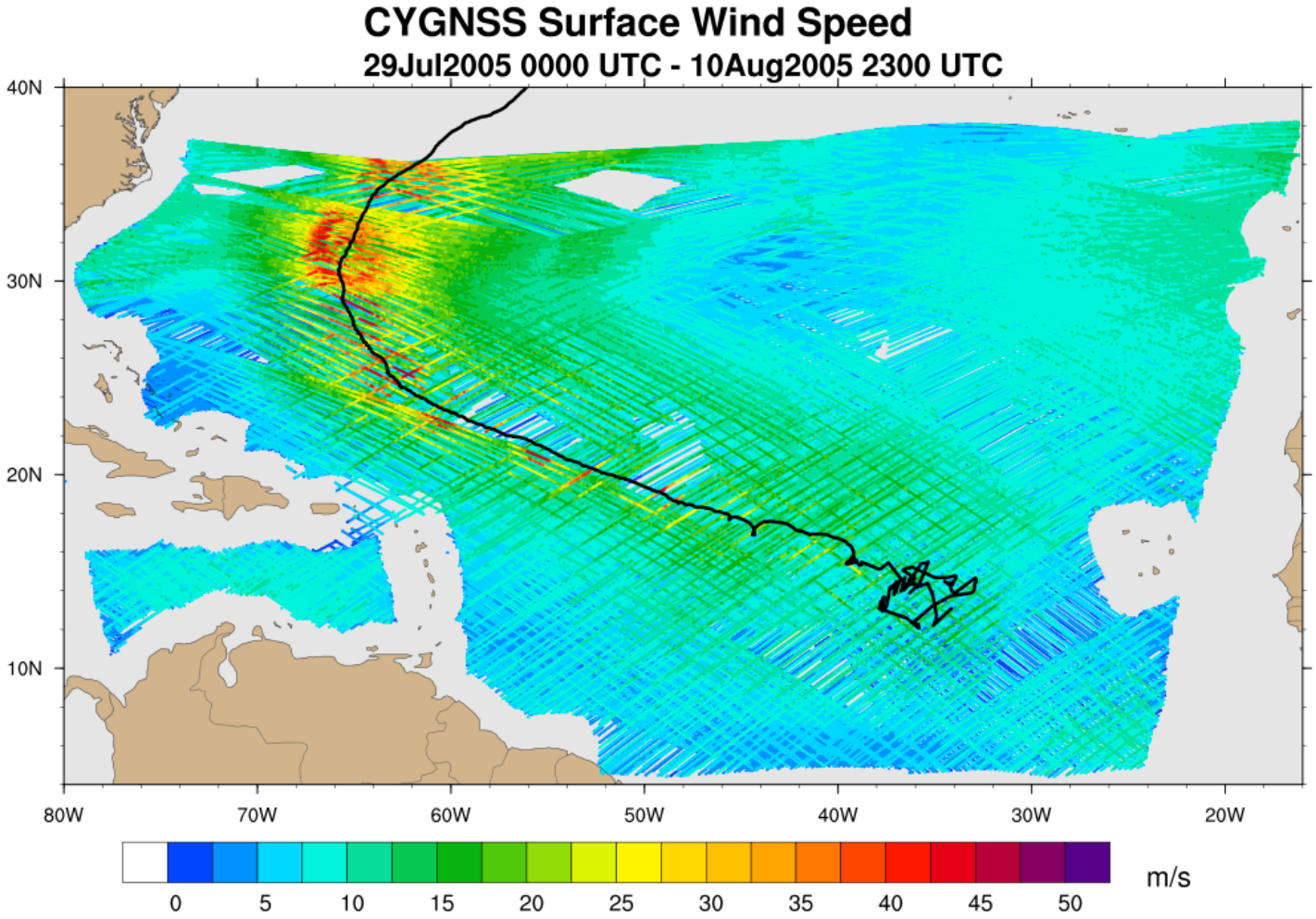


CYGNSS coverage map overlaid on historical record of all named (wind speed >30 kt) storm tracks during 2000-2009. Red indicates Cat 1 or higher TC.

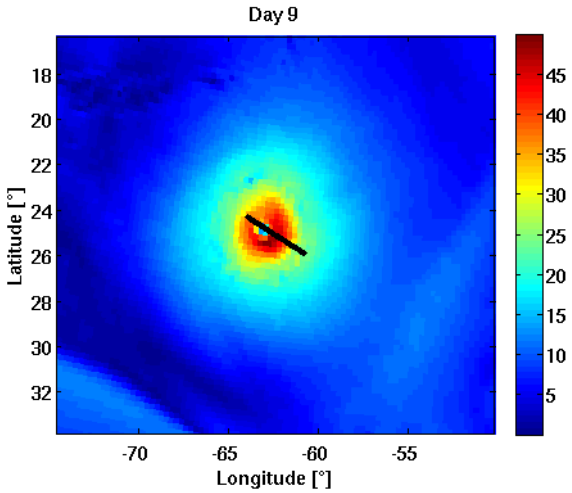
Nature Run Life Cycle
Track, Min. Pressure, Peak Wind speed

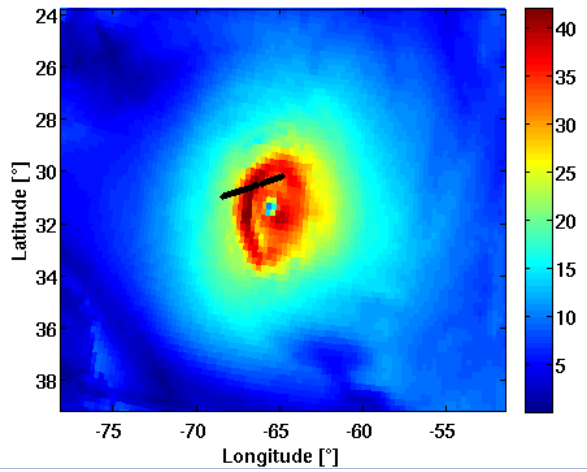


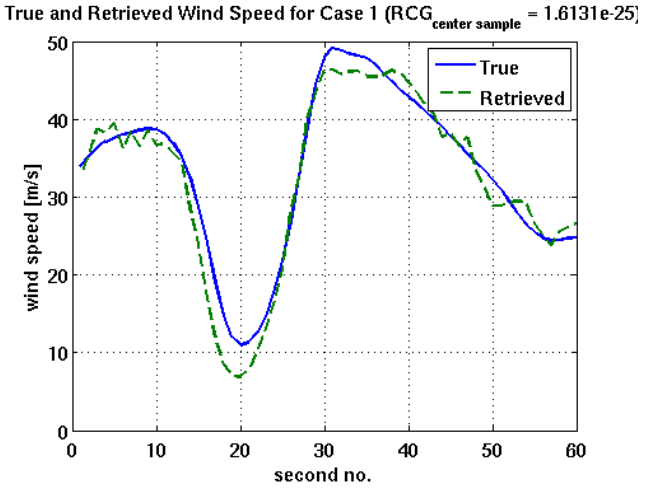
CYGNSS Peak Hold Wind Retrieval for Full 13 Day Nature Run

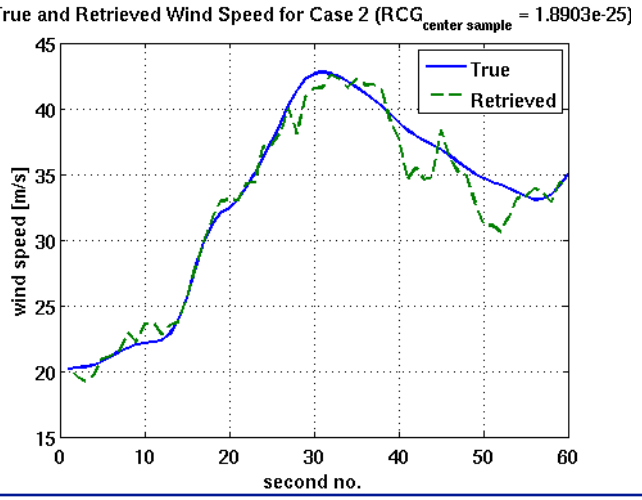


True vs. Retrieved Winds for Storm Center Transects

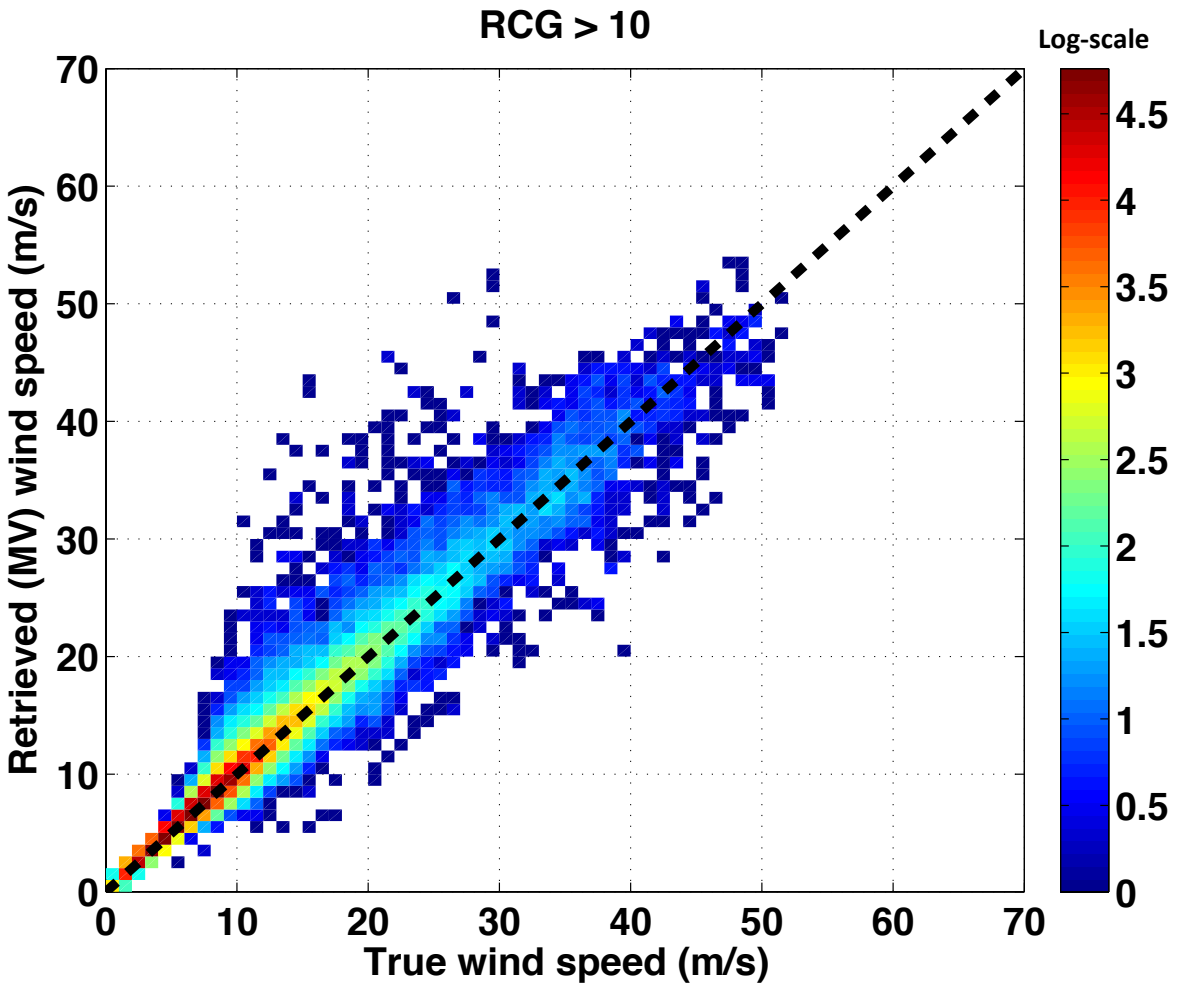








True v. L2 Retrieved Wind Speed



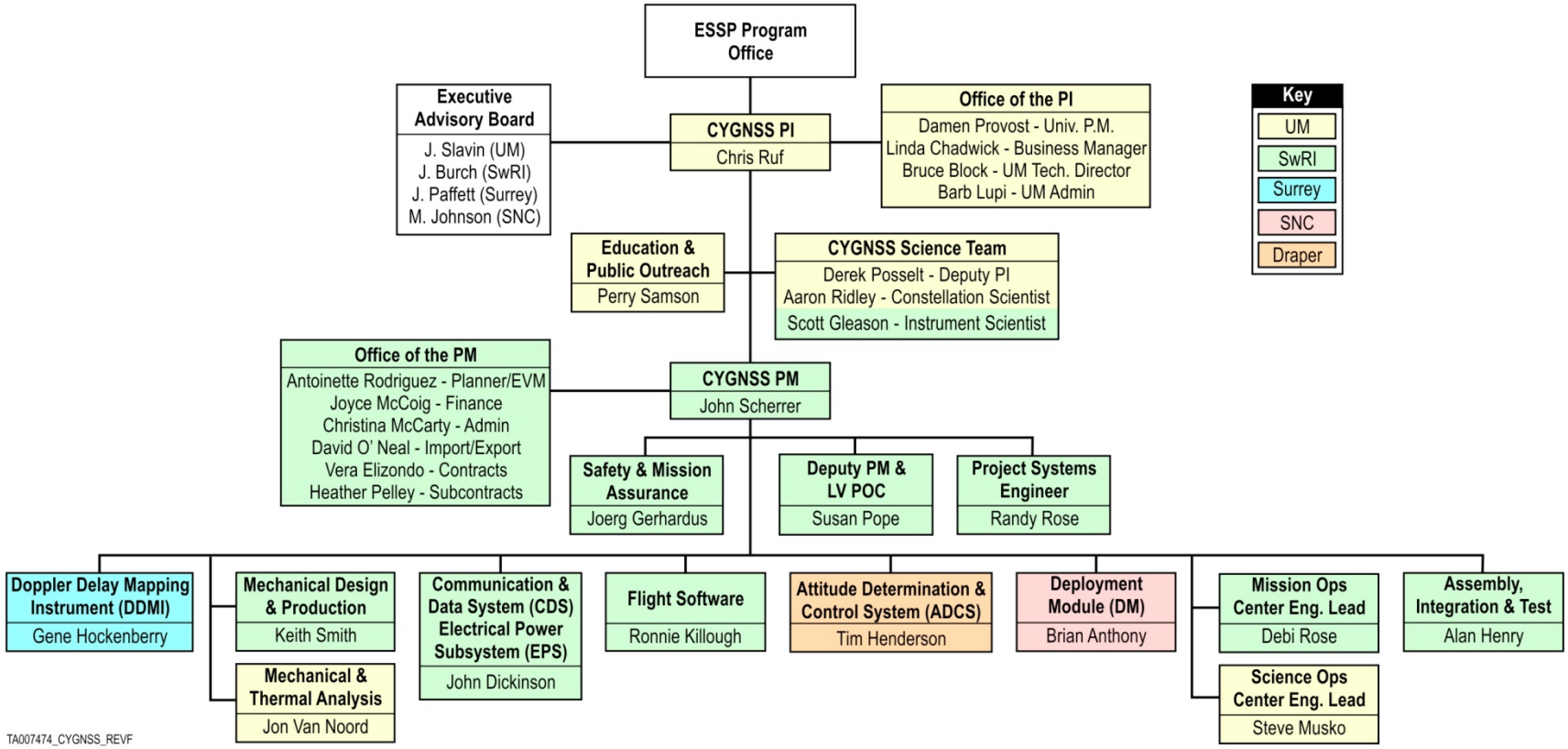
CYGNSS Measurement Performance

Science Objective	Scientific Measurement Estimated Performance	
	Parameter	Performance
Measure ocean surface winds under TC conditions	"Operate through" Precip	< 100 mm/hr (25 km footprint)
	Windspeed uncertainty	Greater of 2 m/s or 10% of windspeed
	Spatial resolution	Variable 15-50 km (ground processing)
	Windspeed dynamic range	< 70 m/s (Cat 5)
Measure ocean surface winds in TC inner core with high temporal frequency	Revisit time	3 hr (median); 7 hr (mean)
	Earth coverage	> 70% coverage of all historical TC storm tracks

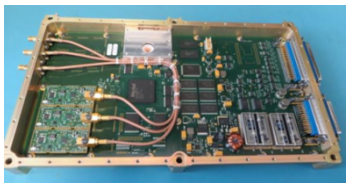
Science Data Products

Data Product	Description	First Data Delivery after IOC	Maximum data latency after first release
Level 0	**Raw data** of total system power (received signal + instrument noise)	2 Months	**6 days**
Level 1a	**Calibrated DDMs** of received power	2 months	**6 days**
Level 1b	**Cal'd DDM** of bistatic radar cross section	2 months	**6 days**
Level 2a	**Spatially averaged windspeed** (plus uncertainty) over a 25 x 25 km^2 region centered at the specular point, geolocated, in spacecraft time & space coordinates	2 months	**6 days**
Level 2b	**Spatially averaged mean square slopes** (plus uncertainty) over a 25 x 25 km^2 region centered at the specular point, geolocated, in spacecraft time & space coordinates	2 months	**6 days**
Level 3a	**Wind speed, gridded** in space and time (1/4° lat and long, 3 hours)	3 months	**6 days**
Level 3b	**Wind speed, gridded and optimized** for observing system experiment data assimilation (optimized spatial and temporal resolution)	3 months	**6 days**

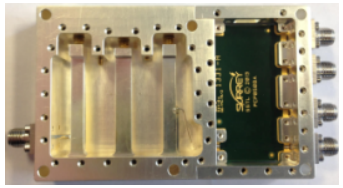
CYGNSS Organizational Chart



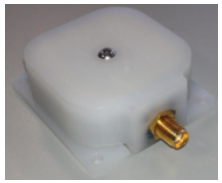
Key Mission Elements (1/2)



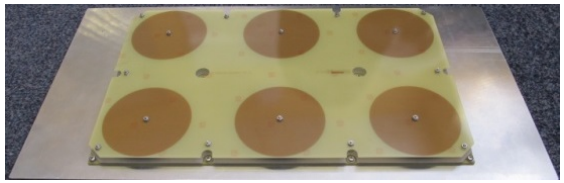
Delay Mapping Receiver



Low Noise Amplifier
(1 of 3)

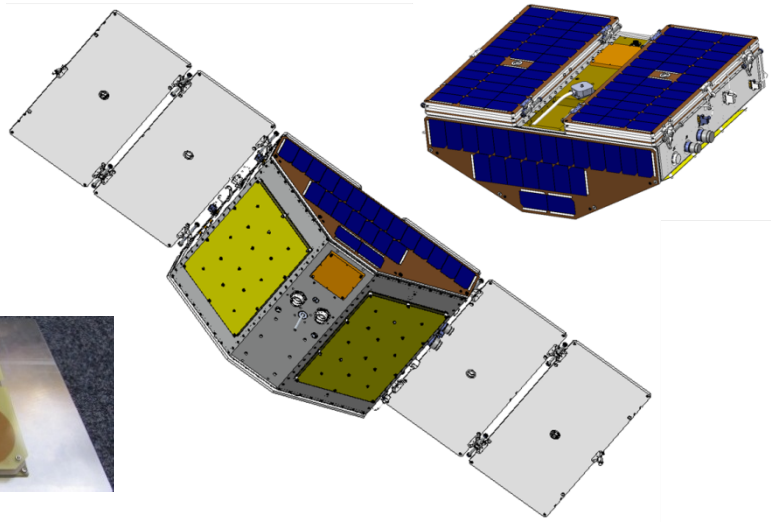


Zenith Antenna

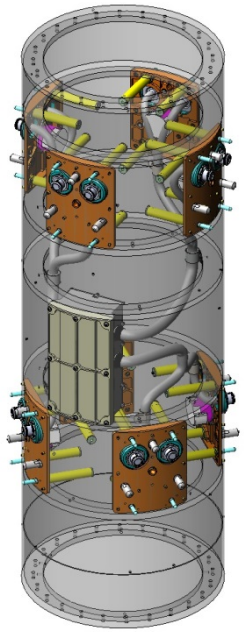


Nadir Antenna (1 of 2)

Science Payload: Delay Doppler Mapping Instrument (DDMI)
-Surrey-



MicroSats (8)
-SwRI-



Deployment Module (DM)
-SNC-

Launch Vehicle: Government Furnished Pegasus XL

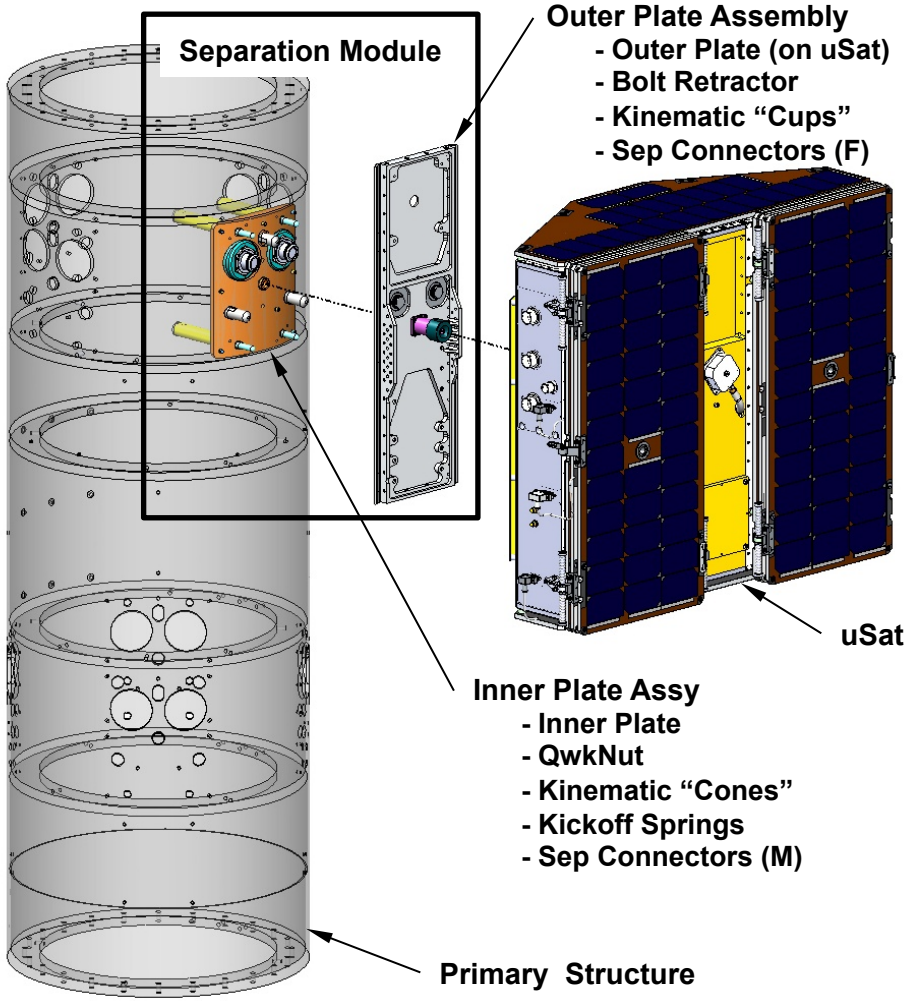
Key Mission Elements (2/2)

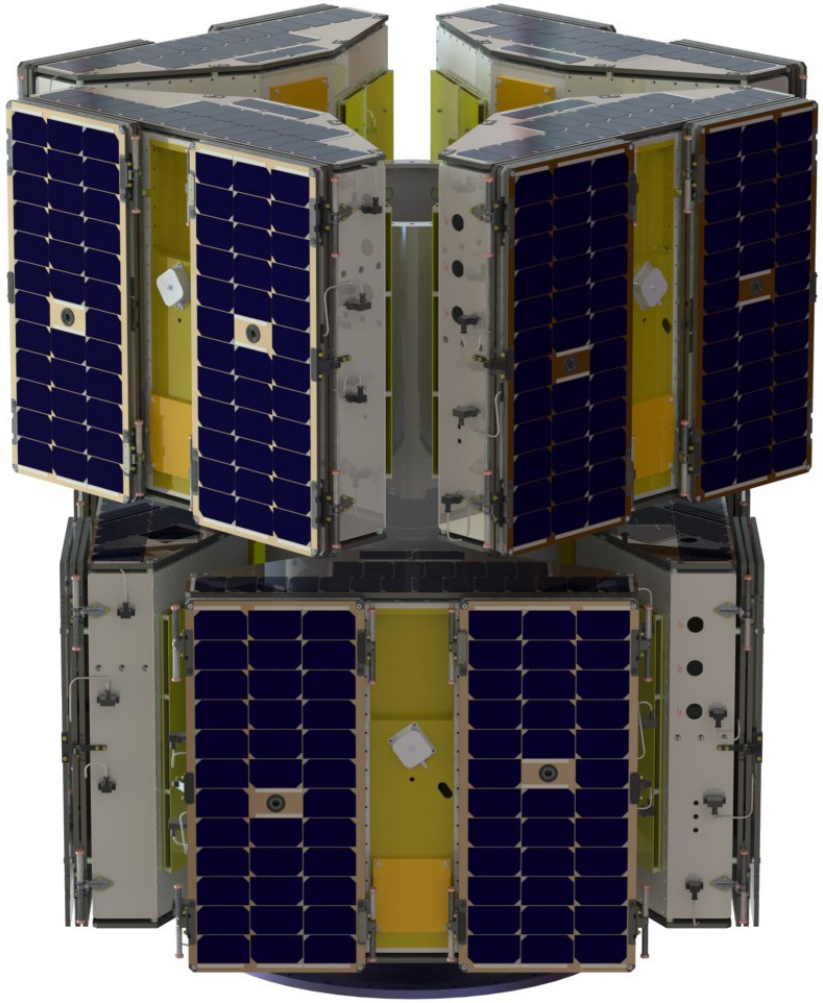
Ground Network
-USN-

Mission Operations Center (MOC)
-SwRI-

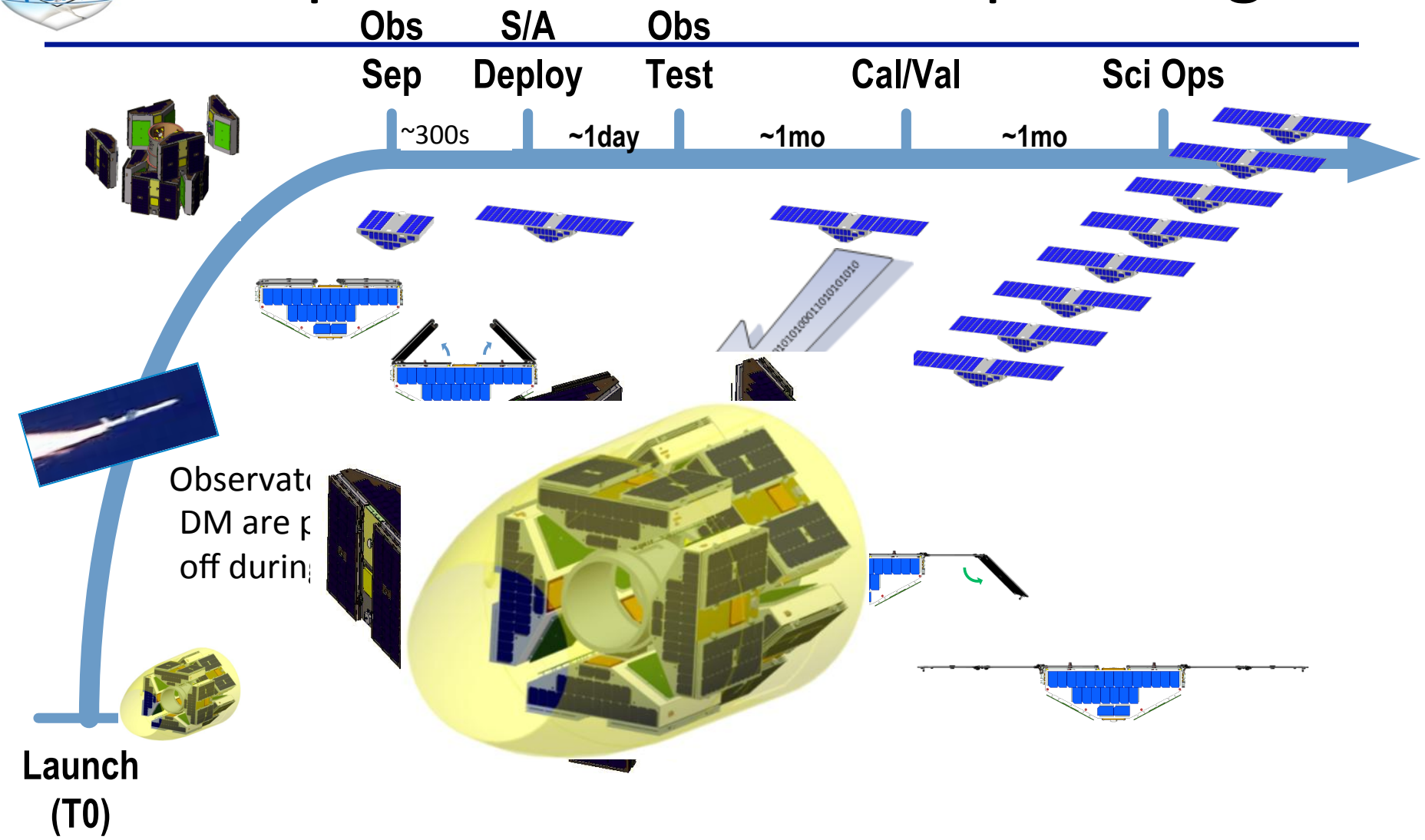
Science Operations Center (SOC)
-UM-

Deployment Module Overview



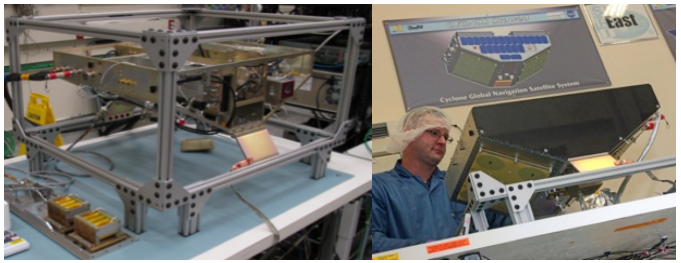


Operational Phase Sequencing

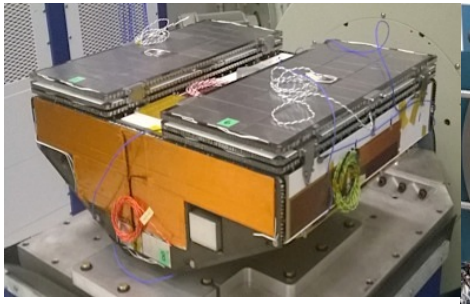


Engineering Models Reduce Flight Hardware Risk

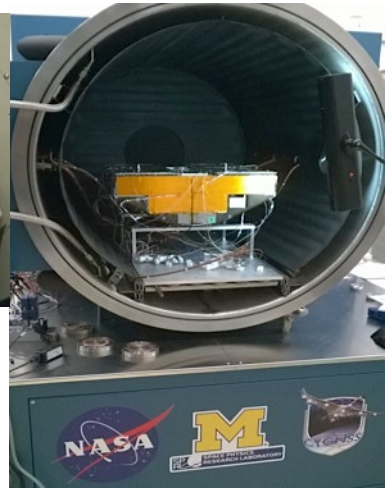
- Engineering Model (EM) has completed initial AI&T efforts
  - Verified mechanical, electrical, and software performance and interfaces
  - Verified Ground Support Equipment (GSE) interfaces
  - Provided personnel training and procedure development
- Structural Thermal Model (STM) has completed low level vibration testing and thermal balance testing
  - Results from vibration testing and thermal vacuum testing used to calibrate Structural and Thermal analysis models
  - Demonstration of thermal and structural design and performance
- Radio Frequency Model (RFM) testing inside anechoic chamber completed
  - Accomplished performance characterization of the RF systems and validated the RF analytical models of the antenna performance
  - Used for both L-band and S-band system testing



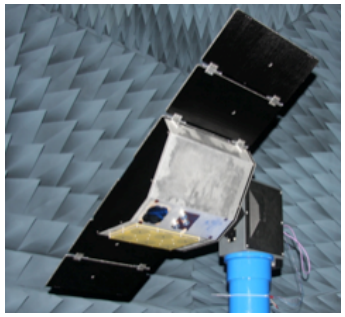
Engineering Model in AI&T High Bay



STM on Vibe Table

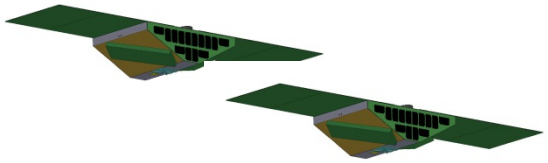


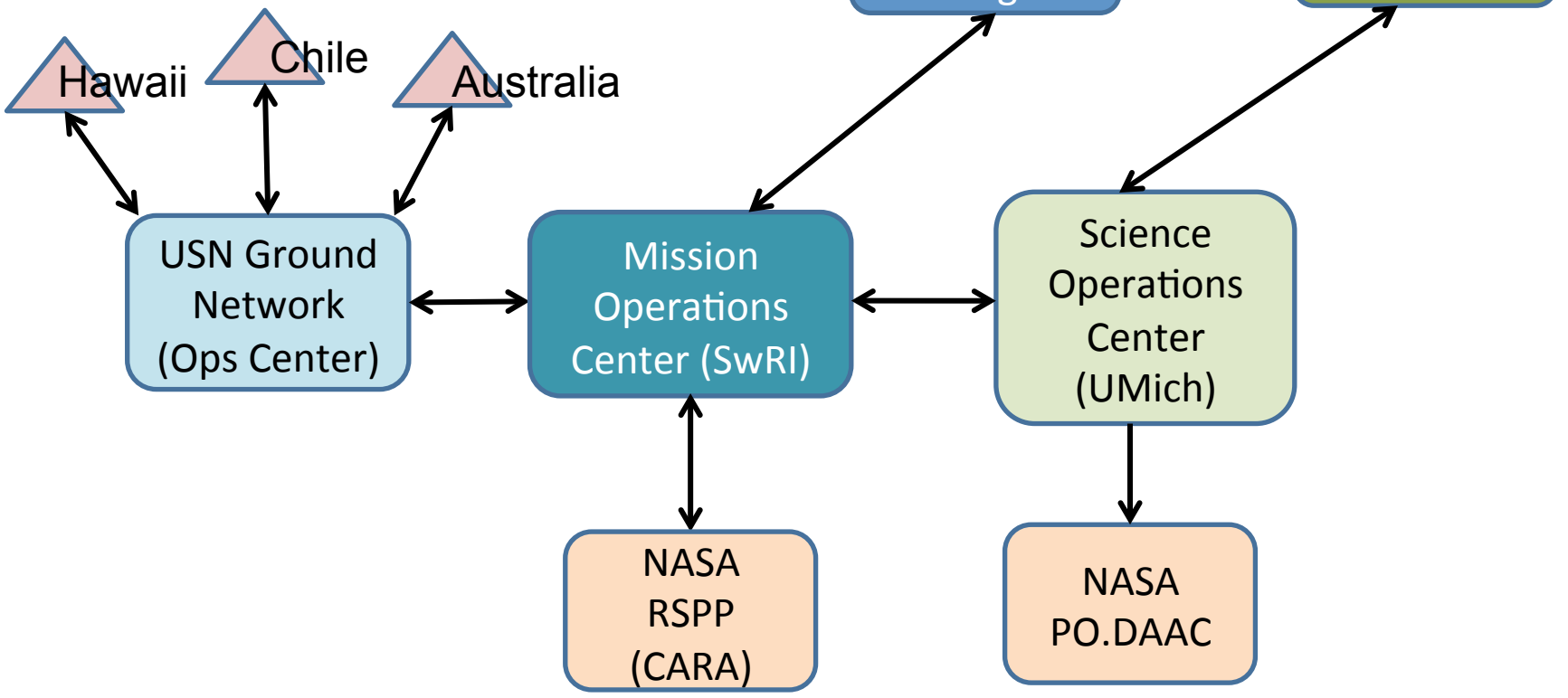
STM in Thermal/Vacuum Chamber



Radio Frequency Model in Anechoic Chamber

Ground System Block Diagram





Project Schedule

Date	Milestone
Dec 2012	Project start
Jun 2013	System Requirements Defined
Jan 2014	Overall System Design Completed
Jan 2015	Detailed Design Completed
Mar 2015 – Jun 2016	Build, Assemble & Test the Spacecraft
Jul-Aug 2016	Integrate Spacecraft and Launch Vehicle
Oct 2016	LAUNCH
Oct 2016 – Mar 2017	Spacecraft commissioning, Science payload and algorithm calibration and validation
Oct 2016 – Sep 2018	On-orbit Mission Lifetime
After Sep 2018	Extended mission

25

Thank You

for more information visit **http://cygnss-michigan.org**

Or contact Chris Ruf, **cruf@umich.edu**